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The SAN DIMAS EXPERIMENTAL FOREST

Lawrence W. Hill

1963 PSW

Pacific Southwest Forest and Range
Experiment Station - Berkeley, California
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By
Lawrence W. Hill

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U.S. Department of Agriculture, Forest Service
Pacific Southwest Forest and Range Experiment Station
Berkeley, California
1963

ACKNOWLEDGMENTS

The San Dimas Experimental Forest is maintained by the Forest Service, U.S. Department of Agriculture in cooperation with the California Division of Forestry. Since 1947 this has been a joint research project with the California Division of Forestry, which participates in program planning and provides financial support. Other long-term cooperators are the Los Angeles County Flood Control District, the Los Angeles County Fire Department, and the University of California which provide staff or other support or use research facilities at the experimental forest.

Special recognition is due these agencies and the California Department of Water Resources for assistance with emergency rehabilitation work after a wildfire in July 1960. Their cooperation made it possible to restore experimental facilities and start emergency research on methods of managing chaparral watersheds for more effective control of fires, floods and erosion, and water yield.

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Lawrence W. Hill

SOUTHERN CALIFORNIA'S WATER AND WATERSHED PROBLEMS

Supplies.--Southern California contains most of the State's population, but little of its streamflow. Consequently, this section of the State must import much of the water it uses (2.5 million acre feet in 1960 - 3.1×10^6 cubic meters). Despite the imports, 60 percent of the water used in the South Coastal Basin (the most populous region of southern California) originates in local mountain watersheds. Much of it reaches valley aquifers from which it is withdrawn for use. Local water of high quality will always be in demand. As in ancient civilizations, continued prosperity is dependent on wise use of mountain watersheds.

Flood Problems.--Heavy winter rains often loose debris-laden torrents from the rugged, unstable mountains. These floods--especially on recently burned-over watersheds--have caused losses of life, and property damage amounting to millions of dollars. The mud, rocks, and boulders from mountain slopes choke water-storage reservoirs and seal waterspreading basins used to recharge groundwater supplies, and flood waters are wasted to the sea.

To combat flood damages, Federal and local agencies have spent $700 million on flood-control structures. At a cost of more than $50 million a year, a dual battle is being fought to halt devastating floods and to provide ample water for farms, factories, and kitchen faucets.

THE SAN DIMAS EXPERIMENTAL FOREST

The Forest Service started preliminary studies in southern California more than 40 years ago to seek more information about the influences of watershed conditions upon water supply, floods, and erosion. These studies were continued by the California Forest and Range Experiment Station (now the Pacific Southwest Forest and Range Experiment Station) in 1927 soon after its establishment. The San Dimas Experimental Forest was set up as a center for watershed research in 1933 with the cooperation of the State of California, county and municipal agencies, conservation groups, water companies, engineers, and agriculturists.

The experimental forest includes 17,000 acres (6,885 hectares) within the Angeles National Forest in the San Dimas and Big Dalton drainages. This research area has several desirable features:

(a) It is representative of much chaparral-covered mountain land in southern California.

(b) It is separated from the main San Gabriel Mountain mass by deep canyons which minimize the chance of underground water movement into the area.

(c) The two major drainages contain several tributary watersheds of intermediate size and many small watersheds which can be studied.

(d) The soil supports a variety of vegetation types.

(e) The San Dimas and Big Dalton dams, built and maintained by the Los Angeles County Flood Control District, provide measuring controls for the major drainages.

GEOLOGY AND PHYSIOGRAPHY

In the 700 to 1,000 million years since the oldest known rocks in the area were formed, several periods of submergence and uplift have occurred. Between these periods the oldest rocks and many others have been subjected to most of the recognized types of alteration, such as folding and faulting, extensive weathering and erosion, extreme heat, and pressure. The result is a complex body of metamorphic and igneous rocks. During the uplift stages many faults were developed which determined the pattern of today's main canyons, and the rocks were extensively and deeply fractured.

The larger drainages are dissected into numerous smaller ones (table 1) which range in area from less than 0.1 square mile (0.26 square kilometer) to more than 15 square miles (38.8 square kilometers). They are generally fan shaped and have short, steep stream channels and precipitous side slopes. The average slope of the land is near the angle of repose for unconsolidated soil material--68 percent. Channel gradients exceeding 30 percent are not uncommon.

SOIL CHARACTERISTICS

The soils found on the experimental forest are generally residual and immature, moderate to coarse textured, normally intermixed with large amounts of fractured rock, and very unstable. They usually have no profile development, average less than 3 feet (.91 meters) deep, and have low water-retention capacity. As a rule, the soils merge into the underlying parent rock. Of 7 soil series on the area, only 2 are of major importance. These soils, yet unnamed, cover the majority of the experimental forest.

One of the two, tentatively called "A" soils, are derived from diorites, granodiorites; schists, and gneiss. They are coarse-textured, sandy loams, shallow (mostly less than 3 feet deep), and excessively drained and are commonly found on steep slopes up to 4,500 feet (1,372 meters) above mean sea level. They range from neutral at the surface to slightly acid at about 2 feet (.61 meters) below the surface. The profile

is gravelly and stoney throughout, and the boundary between the soil and underlying parent material is very gradual and often not distinguishable from parent material. The "A" soil has a weak, angular, blocky structure. Its consistency is loose when dry, and loose to friable when moist.

The other common soils, tentatively called "B," are derived from gneiss. "B" soils are coarse-tectured sandy loams, fairly deep (often 5 feet (1.52 meters) and greater) well-drained, and have high waterholding capacity. Where gneiss is extensive, "B" soils occur on all slopes and aspects, although they are shallower on south-facing extremely steep slopes. "B" soil is slightly acid throughout the profile. The profile is more developed than that of the "A," and there is little surface rockiness and very little stoniness within the profile. Some, in areas of pure gneiss, are entirely free of rocks. "B" soils have a moderate to strong and fine to medium, angular blocky structure. When dry, the soil is slightly hard but becomes very friable when moist.

CLIMATE

A Mediterranean-type climate prevails--dry, hot summers, and rainy, mild winters. Only 175 days a year (29-year period of record) have cloud cover greater than 0.3 of total closure. Maximum summer temperatures frequently surpass 100°F. (37.8°C.) and winter minima are seldom below 25°F. (-3.9°C.). The mean monthly temperatures, based on 27 years of record, range between 46.8°F. (8.2°C.) in January to 72.1°F. (22.3°C.) in July and August (table 2). The average annual temperature is 57.9°F. (14.4°C.), and the average annual evaporation is 64.0 inches (1,628 mm.).

Annual precipitation, in 32 years of record, ranged from 48.2 inches to 11.5 inches (1,224 mm. to 292 mm.). The average is 26.7 inches (678 mm.) (table 3). Nine-tenths of the precipitation falls from November through April. Over a 25-year period 50 percent of the total fell in 10 percent of the storms. Frequently, 3 or 4 summer months pass with little more than a trace of rain. Nearly all of the precipitation occurs as rain, but snow occasionally falls at the higher elevations.

VEGETATION

Fire denuded most of the watersheds in July 1960. Before the fire, two major plant formations prevailed--chaparral and woodland chaparral.

Chaparral, a dense growth of many shrub species, covered most of the area and included three types: chamise-chaparral type, sage-buckwheat type, and scrub oak type. Because of its flammability the chaparral formation presents the most critical watershed management problem. When destroyed by fire, sudden increases in erosion and floods result.

Chamise (Adenostoma fasciculatum) was the most widely distributed species of the chaparral formation. It occurred in pure and mixed stands on all sites except north-facing slopes and extremely dry south-facing

slopes. This species is often associated with ceanothus (*Ceanothus* spp.), white sage (*Salvia apiana*), black sage (*Salvia mellifera*), manzanita (*Arctostaphylus glauca* and *A. glandulosa*), and other minor chaparral species.

The sage-buckwheat type dominated dry sites, which usually have unstable soil. Its principal members are white sage and California buckwheat (*Eriogonum fasciculatum*).

The scrub oak type grew on north-facing slopes but sometimes on south-facing slopes above 4,000 feet (1,219 meters). This type is composed mostly of California scrub oak (*Quercus dumosa*) and hairy ceanothus (*Ceanothus oliganthus*), with other chaparral species entering within their range.

The woodland-chaparral formation includes the live oak-chaparral, live oak-woodland, and bigcone Douglas-fir forest types. Only the first two types were found in any abundance on the experimental forest. They grew principally on north-facing slopes, where vegetation of these types usually is dense. On very steep slopes, however, the cover is considerably more open.

The live oak-chaparral type is usually dominated by shrubby individuals of California live oak, (*Quercus agrifolia*), but on dry sites chaparral species often dominate.

The live oak-woodland type occurred mostly on north-facing slopes and was dominated by individuals of Canyon live oak (*Quercus chrysolepis*) 15 feet (4.5 meters) or more in height. Scattered trees of bigcone Douglas-fir (*Pseudotsuga macrocarpa*) frequently occurred among the oaks. Vegetation density varied from dense to fairly open depending on soil depth and steepness of the slope.

RESEARCH AT SAN DIMAS

Watershed research on the San Dimas Experimental Forest and related studies conducted elsewhere in southern California have these broad objectives:

First, to determine how watersheds function--what happens to the precipitation--how water and soil movement are influenced by vegetation, soil, geology, and topography.

Second, to develop land management techniques for controlling erosion and flood peaks, particularly after fire in steep, unstable watersheds.

Third, to develop land management methods that will produce the maximum yield of clear, usable water.

PRE-FIRE RESEARCH

Rainfall Measurements

One of our first tasks was to learn when rain occurs, how much, and how intensely. We soon found that conventional vertical raingages gave inaccurate rainfall measurements. They were especially inaccurate during high intensity storms when accurate measurements were most needed (fig. 1). After testing raingages of many sizes and shapes, we found that if the receiving rim of the gage were parallel to the mountain slope upon which it is placed, the measurements were much more accurate. Now storage gages are tilted, and recording gages, which must stand vertical, are fitted with funnels cut parallel to the slope (fig. 2). This permits reliable records with much fewer raingages. To meet the needs of expanded research we now sample rainfall with a network of 115 raingages. Most of them are concentrated in special research areas.

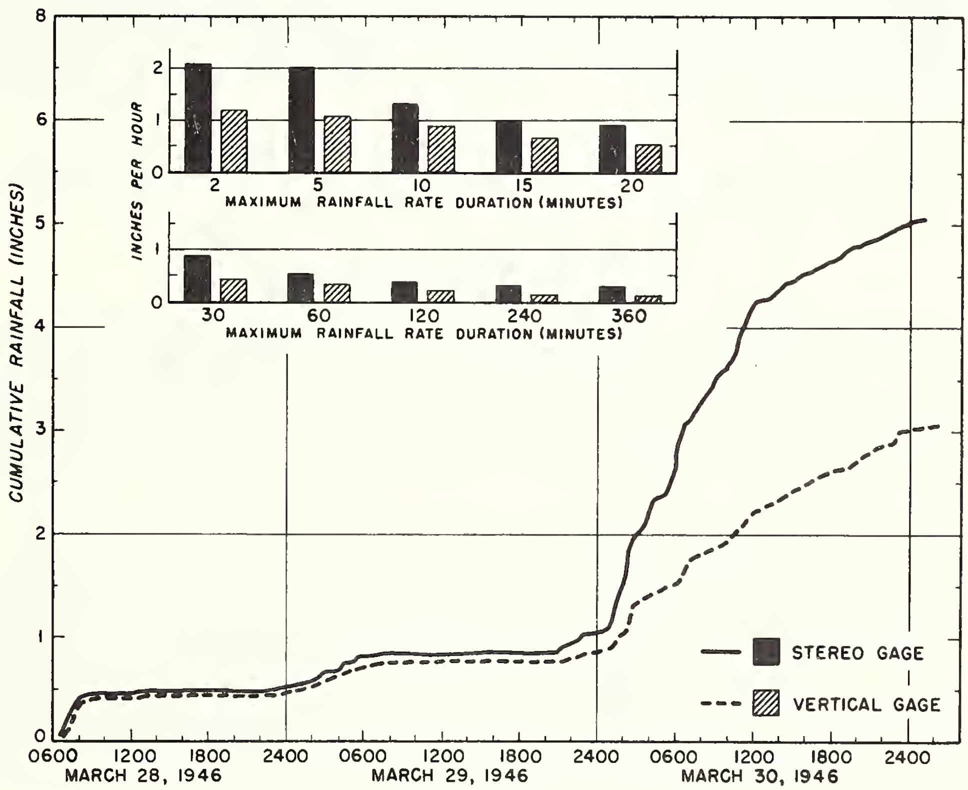


Figure 1.--Comparison of rainfall as measured by a vertical and stereo raingage. Note how the measurements varied as rainfall intensity increased.

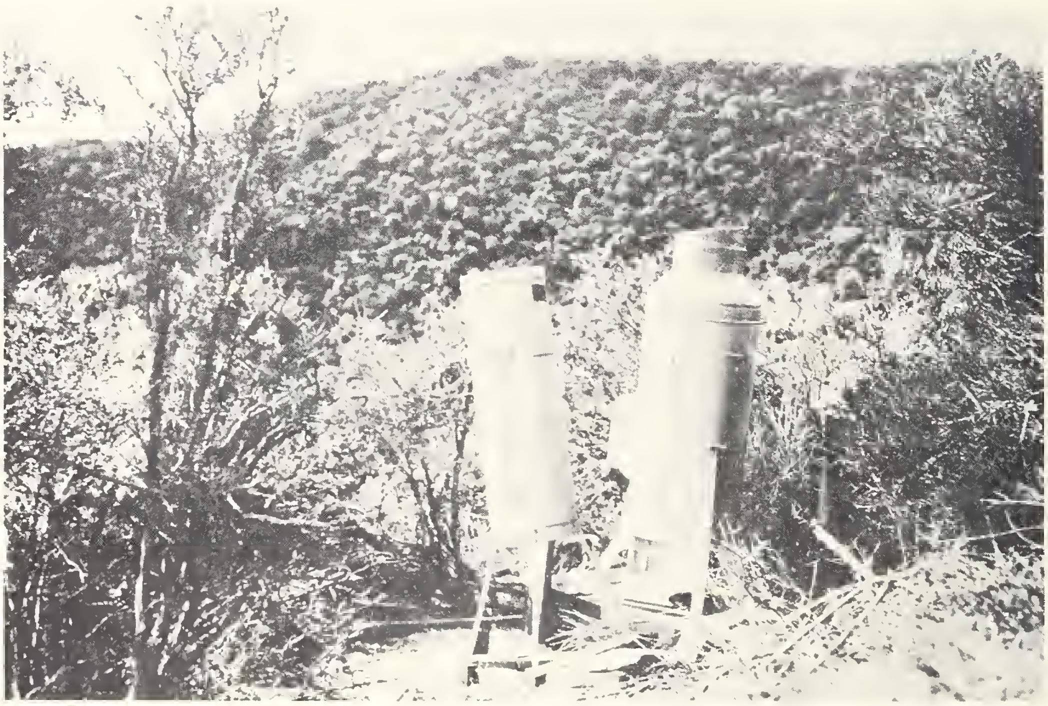


Figure 2.--More accurate measurements of rainfall result when storage gages are tilted (left) and recording gages are fitted with "stereo" funnels (right).

The San Dimas Lysimeters

What happens to the rainfall once it reaches the watershed? How well do brush and other plants serve as watershed cover? How does runoff differ under different plant cover? Does infiltration and percolation of soil water vary under different plant covers? Do some plants use more water than others?

To answer such questions, the San Dimas lysimeters were constructed in 1937 (fig. 3). Ceanothus, buckwheat, chamise, scrub oak, Coulter pine (Pinus coulteri), and grass were planted in separate concrete tanks 10.5 x 21.8 x 6 feet in size (3.2 x 6.6 x 2.4 meters). One tank was kept bare. Electrical instruments transmitted and recorded measurements of rainfall, runoff, and seepage. Colman electric soil-moisture units and later, a nuclear soil-moisture meter, made it possible to measure water movement into and through the soil and evaporative losses from the soil.

As you might expect, the bare lysimeter has produced the most runoff (table 4). Infiltration under the grass, shrubs, and pine was more than twice that of the bare lysimeter.

All available soil moisture under the shrubs and pine was lost to evaporation and transpiration. In most years only under grass did water yield occur as seepage through the soil mass.

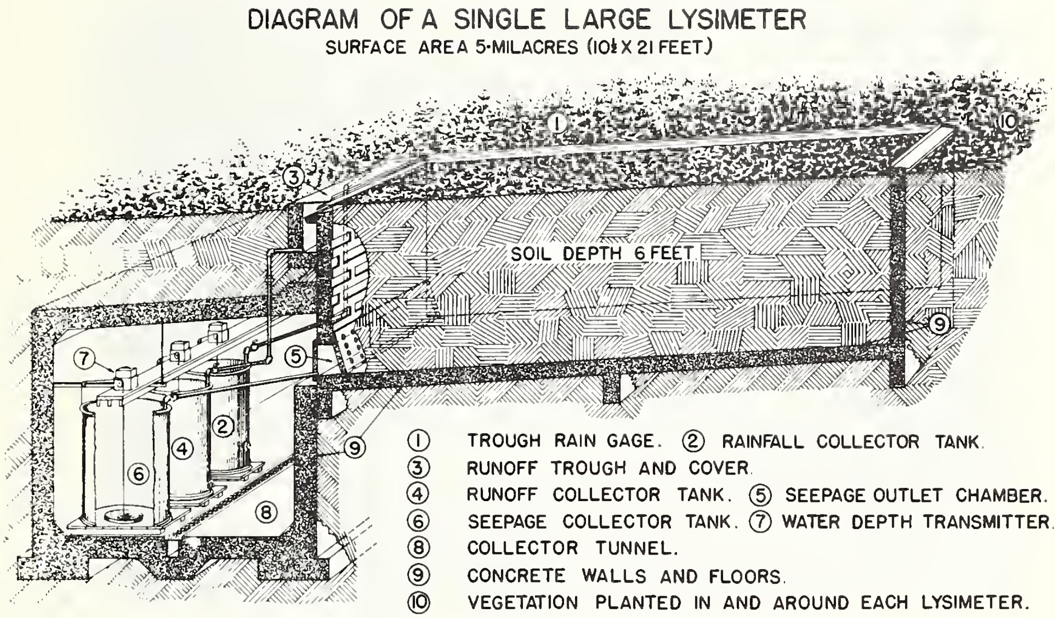


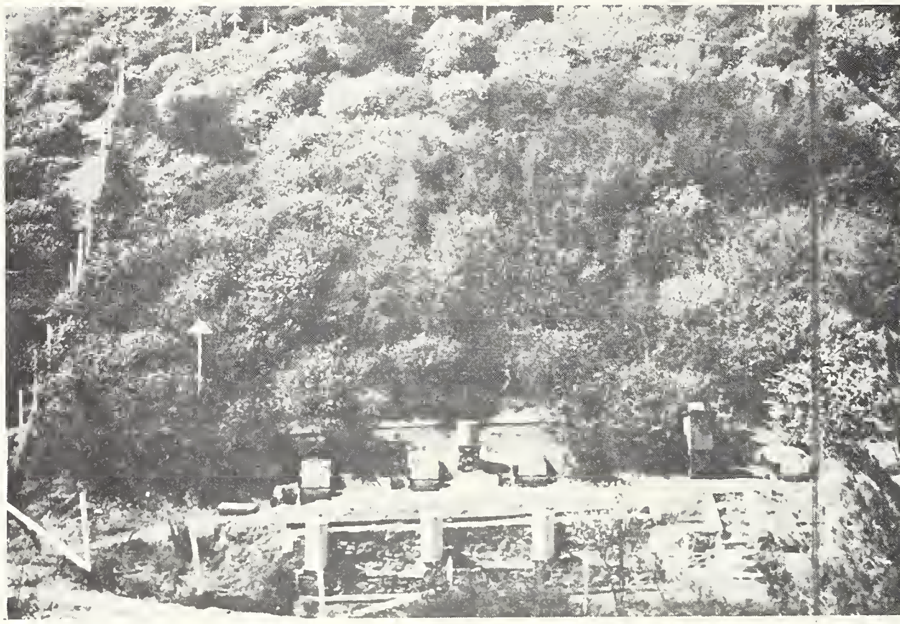
Figure 3.--Diagram of a single large lysimeter. Its surface area is 5 mileacres (21.3 square meters).

Soil Moisture-Runoff Plots

Can we get a greater yield of usable water by replacing chaparral with a shallow-rooted grass cover? For several years we measured runoff, erosion, and soil moisture on 9 hillside plots heavily covered with native brush--mostly scrub oak (fig. 4). These plots are on unusually deep soil, averaging about 12 feet (3.7 meters). In 1951, we cleared six brush plots, planted them to annual ryegrass, and compared evaporation and transpiration losses.

In brief, we found that during a winter of average rainfall, the soils under both brush and grass were wet to field capacity. Then, during the long dry season, evaporation and transpiration dried the brush-covered soils to depths of at least 11 feet (3.4 meters)(fig. 5). At the same time, a substantial soil-moisture saving and potential ground water yield was obtained under the grass cover where the soil was still wet below 3 feet. But the following year when we permitted deep-rooted weeds to invade the grass-covered plots, no soil-moisture gains were recorded.

This study has pointed up three important considerations. Soil moisture savings are obtained only if: (a) the areas converted to grass have soils greater than 3-feet deep, (b) we maintain the grass free of deep-rooted weeds, and (c) rainfall is enough to replace the soil water used by the grass the previous year.



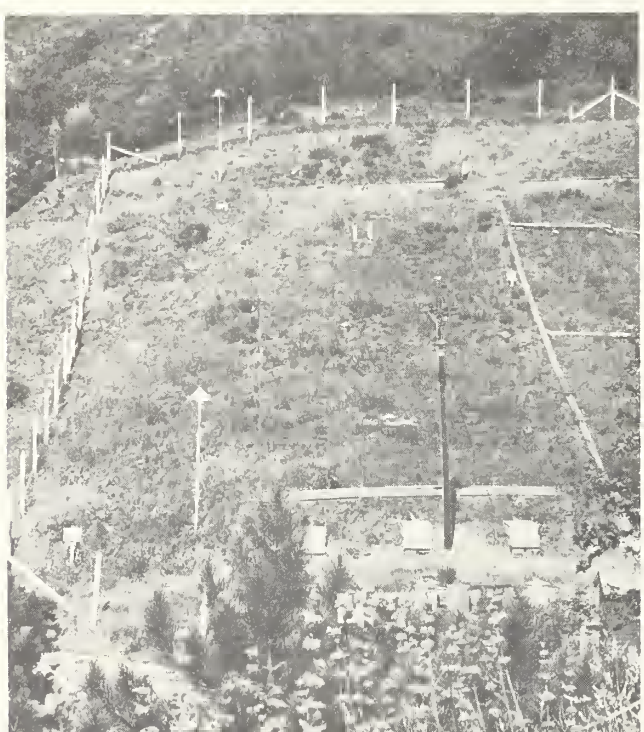


Figure 4.--Soil moisture-runoff plots. Above, the plots with original brush cover; below, the same plots after converting them to a shallow-rooted grass cover.

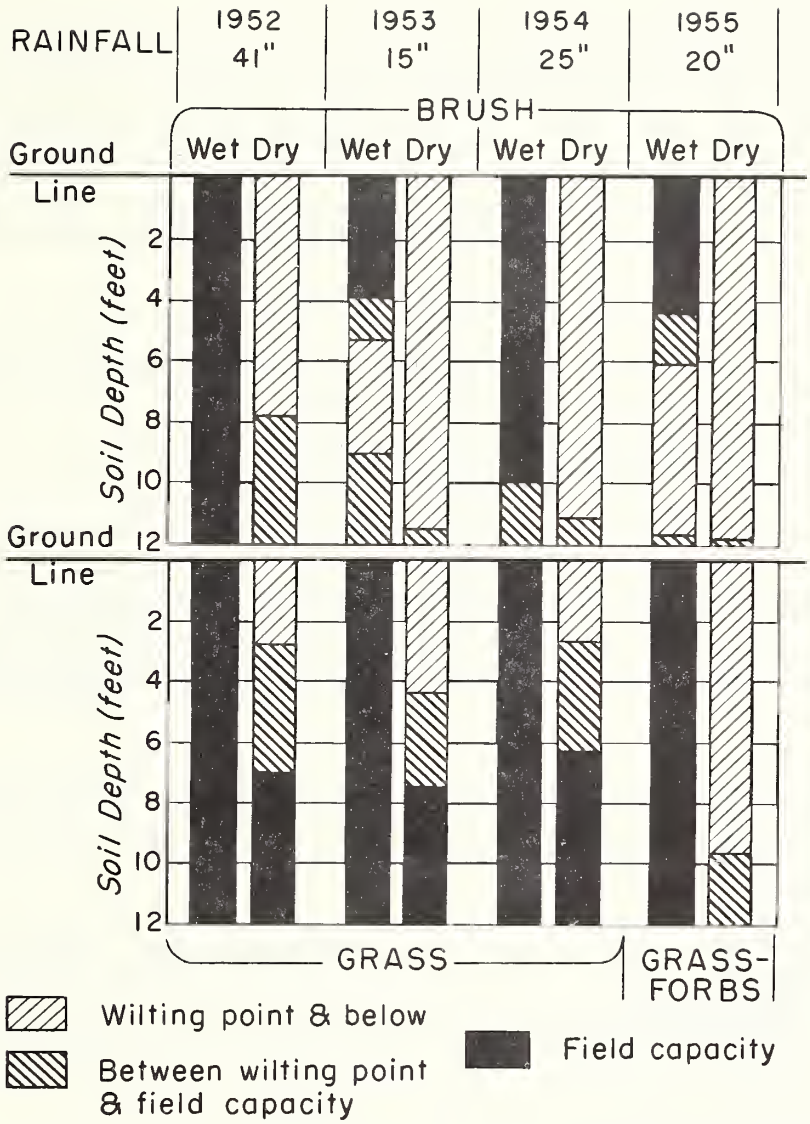


Figure 5.--Soil-moisture differences under brush, grass, and grass-forb cover.

Managing the Watershed

We found that a considerable amount of water was lost each year (table 5). The lysimeter and then the plot studies showed that a grass cover on deep soil might permit a substantial saving of water. Drawing on these results, we started studies of management alternatives on whole watersheds aimed at increasing the yield of usable water.

Bell Watershed Study

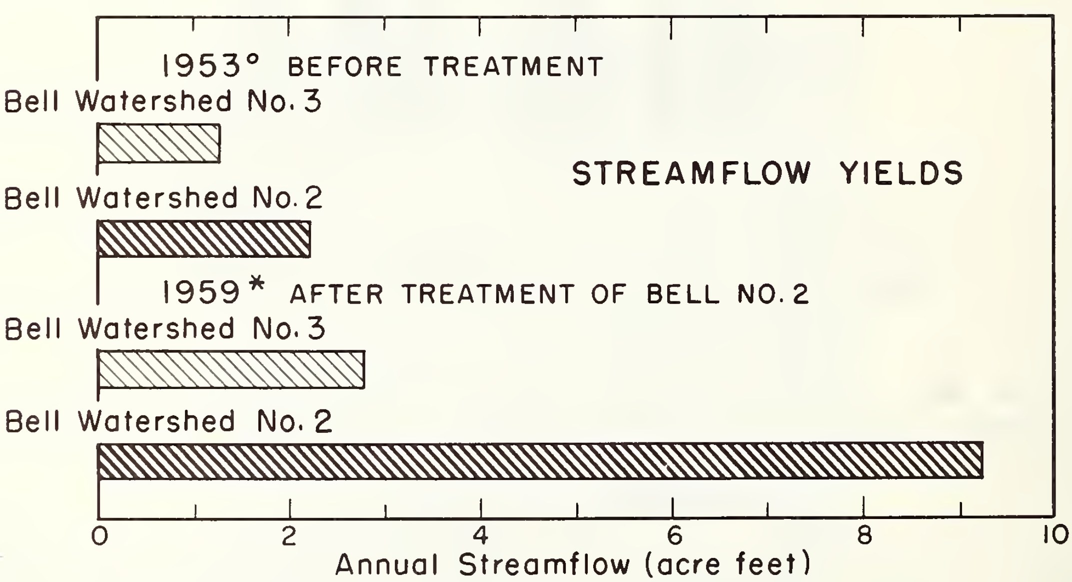
Our first approach was to kill the shrub cover on deep-soil side slopes. Forty acres (16.2 hectares) of chaparral on the deeper soils in

100-acre (40.5 hectares) Bell Watershed No. 2 were aerially sprayed with a mixture of 2,4-D and 2,4,5-T in the spring of 1958, and again in 1959 and 1960. Adjoining Bell Watershed No. 3 was left unsprayed. When comparable periods of current and antecedent rainfall were considered, we found that streamflow in the treated watershed was about 5.5 acre feet (6.8 x 10^3 cubic meters) greater than expected without treatment (fig. 6). This amounts to an annual increase of about one-tenth of an acre foot for each side-slope acre treated (304 cubic meters for each hectare treated).

Monroe Canyon Study

Another management approach was to remove riparian and associated woodland growth along stream channels. Again the results show that we can increase water yield.

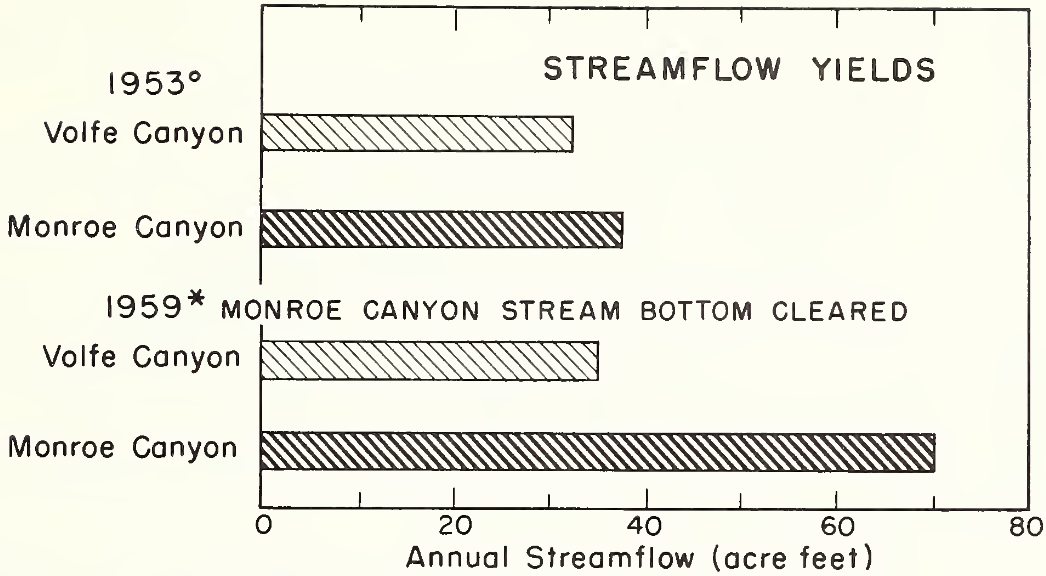
In 1958 and 1959, we removed a total of 38 acres (15.4 hectares) of riparian and woodland trees from the bottom of 875-acre (354.4 hectares) Monroe Canyon. Herbicides were sprayed on stumps and sprouts the first year after removing the trees. The year after removing the channel bottom trees and shrubs--after a very wet 1957-58 winter, streamflow was continuous and amounted to 30 acre-feet (36.9 x 10^6 cubic meters) more than predicted had the vegetation not been removed (fig. 7). Seventeen acre-feet



° June 1, 1952 through May 31, 1953. Rainfall: Current year, 15.9 inches, antecedent year, 40.5 inches.

* June 1, 1958 through May 31, 1959. Rainfall: Current year, 14.9 inches, antecedent year, 47.3 inches.

Figure 6.--Streamflow from managed Bell Watershed No. 2 and unmanaged No. 3 for comparable periods before and after 40 acres of brush was killed on deep-soil side slopes in 100-acre Bell Watershed No. 2.



° June 1, 1952 through May 31, 1953. Rainfall: Current year, 15.9 inches. antecedent year, 40.9 inches.

* June 1, 1958 through May 31, 1959. Rainfall: Current year, 14.9 inches. antecedent year, 47.3 inches.

Figure 7.--Streamflow from managed Monroe Canyon and unmanaged Volfe Canyon for comparable periods before and after 38 acres of stream channel vegetation was removed from Monroe Canyon.

(20.9×10^3 cubic meters) of the increased flow came during the driest part of the year. Before treatment the stream normally dried up in early July. After the very dry winter of 1958-59, dry-season streamflow was still increased 14 acre-feet (17.3×10^3 cubic meters). This effect of management has particular importance because the extra flows came during the dry summer, when water shortages are greatest.

POST-FIRE RESEARCH

July 20, 1960, marked the beginning of a new era in research on the experimental forest. At noon on that day lightning started a fire which, by the next evening, had swept over most of the experimental forest. None of the experimental watersheds was spared. Thanks to prompt action and a great deal of help from State and local agencies, we were able to turn a major scientific disaster to advantage.

The fire left a large area of chaparral land in critically unstable condition. The soils, vegetation, and watersheds of this area had been intensively studied for more than a quarter of a century. Here was a unique opportunity to capitalize on past knowledge--to compare the past with the present. Before the fire was out, plans were started to measure quantitatively the results of restoration, protection, and management

efforts on chaparral lands. The research program now underway is studying:

1. Emergency sowing of burned-over watersheds
2. Erosion control
3. Conflagration control
4. Improvement of water yield

Emergency Sowing of Burned-Over Watersheds

By the end of November 1960--4 months later--a total of 13,496 acres (5,465.9 hectares) had been sown by helicopter to several annual and perennial grasses and black mustard (Brassica nigra). An additional 83 acres (33.6 hectares) were sown by hand, and 29 acres (11.7 hectares) were sown with a heavy rangeland drill. The purpose of this "first aid" treatment was to establish a temporary cover for protection of the watershed while the brush slowly recovered.

The annual species were sown mostly on shallow soils. They are hardy and reseed themselves each year, and their seed is abundant and cheap. Black mustard used to be the most commonly sown species but it has largely been replaced by common ryegrass (Lolium multiflorum) in southern California. On some of the smaller San Dimas watersheds we sowed a mixture of the two species. Two other annuals--Wimmera 62 ryegrass (Lolium rigidum) and blando brome (Bromus mollis)--were sown over large areas. We are asking "Which annual provides the best cover on different sites?"

Deep-rooted perennial grasses have been suggested for emergency cover. Where permanent cover is desired, perennials have been commonly drill-sown, but they have never been sufficiently tested on burned-over southern California watersheds. We are now comparing them with annuals in the experimental watersheds to see if they provide better cover, especially at upper elevations too cold for good growth of annuals. We are testing individual species and mixtures of species as both emergency and permanent cover.

Erosion Control

When rainstorms hit fire-denuded southern California watersheds, some of the world's highest runoff and erosion rates result. A study of a San Dimas watershed which had only one-third of its vegetation destroyed by fire in 1953 showed that peak storm-flow the first storm after the fire was 128 times as great as expected had the watershed not burned. Total storm discharges for the first and second storm after the fire were 5.2 and 3.0 times greater, respectively, than expected. Stormflows were bulked with debris washed from the burned slopes and stream channels below. Flows from the adjoining unburned comparison watershed were comparatively clear.

We have also found that erosion can be a problem without rain. In one study during a year of little rain, dry soil sliding down-slope

exceeded water-born erosion. After a fire, dry-season erosion was 2 to 35 times the pre-burn rate.

We are now well into a program of testing several "first aid" treatments aimed at reducing post-fire flood and erosion damage. Tests include large contour trenches, grass seeding, channel check dams, and contour row plantings of barley. We applied these treatments to 25 small watersheds (table 6 and map inside of back cover) ranging in size from 2 to 8 acres (.8 to 3.2 hectares). Except for an untreated control watershed, each one contains one or more of these treatments. All have a flow measurement flume and a debris basin.

Contour Basin Trenches

Large permanent trenches (terraces) were constructed in nine of the watersheds (fig. 8). This practice was developed in the Intermountain Region of the Forest Service. The trenches were constructed with a heavy bulldozer and were spaced on contour 40 to 90 feet (12.2 to 27.4 meters) apart, depending on slope. A completed trench system provides dead storage for a storm that produces 3 inches of rain (76.2 mm.) or for 550 cubic yards of sediment per acre (420.5 cubic meters per .405 hectares).

Figure 8.--Completed trench. The basins hold runoff and lessen the lateral movement of water within the trench.

Broadcast Sowing of Perennial Grasses

A mixture of perennial grasses with a small amount of annuals was sown at a rate of 20 pounds per acre (22.7 kg. per hectare) in 4 watersheds, and at $4\frac{1}{4}$ pounds (5 kg.) in 4 others. Harding grass (Phalaris tuberosa var. stenoptera), tall wheatgrass (Agropyron elogatum), intermediate wheatgrass (Agropyron intermedium), and smilograss (Oryzopsis miliacea) were the dominant perennials used.

Broadcast Sowing of Annual Grasses

Nine other watersheds were sown with annual grasses--5 at 20 pounds per acre and 4 at $2\frac{1}{2}$ pounds (2.8 kg. per hectare). The mixture was composed of four parts Wimmera 62 ryegrass and one part blando brome.

Stream Channel Checks

Small dams were constructed of cement combined with soil and rock available at the dam sites in nine of the watersheds (fig. 9). The purpose of these dams is to prevent channel downcutting, to stabilize side slope soils, and to spread out streamflow and thus reduce its velocity and erosive power.

Figure 9.--Stream channel checks. Their purpose is to prevent channel downcutting and to stabilize canyon side slopes.

Figure 10.--Contour row planting of barley. Barley impedes overland flow of water and sediment.

Contour Row Planting of Barley

Barley seed and fertilizer were placed in furrows in nine small watersheds to form dense rows on 2-foot (.61 meters) contour intervals (fig. 10). Barley (Hordeum vulgare var. Atlas) was chosen because it grows more vigorously than most species during cool winter weather. The fertilizer was included to promote earlier and heavier growth. The purpose of this treatment is to impede overland flow of water and sediment on side slopes.

Preliminary Results of Erosion Control Tests

Eighteen months after these first-aid treatments were applied, we were able to make some tentative conclusions about their effectiveness:

1. Drought conditions during the first growing season did not favor grass growth. After two months of heavy rain in 1962, however, the annual grasses began to develop a good cover. In the future we expect this treatment to modify floods and erosion.

2. Barley contour-row plantings (alone and in combination with trenches) seem to be our best first-aid treatment.

3. Contour basin trenches failed when unaided by barley plantings. However, we repaired failures and redesigned probable failure areas in order to continue tests of trenches for emergency treatment in southern California.

4. Flood peaks and sediment were associated with intensity of rainfall rather than with the total size of the storm. Most sediment transport and debris movement occurred within minutes after bursts of high intensity rainfall. When intensities exceeded 1/2 inch (12.7 mm.) per hour, large peak flows and debris loads usually followed.

Estimates of time, costs, materials, and other pertinent data for the erosion control treatments are presented in table 7.

Mustard-Ryegrass Watersheds

Eleven other watersheds ranging in size from 9 to 87 acres (3.6 to 35.2 hectares), each with a flume to measure flows and suspended sediment, are dedicated to a comparison of ryegrass and mustard as emergency vegetative cover. This is the first time it has been possible to make a quantitative comparison of these alternatives. In 18 months since installation, no differences have become evident.

Lysimeter Tests

The burned-over lysimeters have been replanted for a new study. It seeks to answer the question"How do infiltration rates differ under mustard or ryegrass covers?" If one plant induces more infiltration and percolation than the other, runoff would be less, and presumably erosion rates would also be less. We also plan a water-use study to evaluate water requirements of several species of phreatophytes.

Soil Binding Chemicals

The use of soil binding chemicals was also explored. We had hoped to find a chemical that would increase infiltration and stabilize the soil during the early part of the rainy season before an effective plant cover

could be established on burned slopes. Twelve chemicals were studied in the laboratory, and three of these were tested in large field plots under artificial rainfall.

Our results showed no significant differences between the treated and untreated plots. The thin crust of soil and chemical binder decreased infiltration rates and in turn increased surface runoff and debris production. So far we have not found soil binding chemicals that will work as well on burned-over watersheds as they do on highway cuts and fills and on landscaping projects for controlling wind and water erosion.

Conflagration Control

An obvious first step in reducing erosion and flood damage is to prevent widesacle destruction of the vegetation by disastrous fires. The few fires which escape early control, usually under extreme weather conditions, often build up into conflagrations. Where terrain is extremely steep, and the heavy fuels are tinder dry, such fires cannot be readily stopped in the continuous cover of dense brush.

Firefighting agencies and researchers are trying a new approach: to modify fuel conditions by breaking the expanses of brush into smaller units. Modification is done by converting the dense brush to a cover of light-volume fuel, such as grass, on wide strips or blocks of strategically located land. These converted areas are called fuel-breaks (fig. 11).

Firefighting agencies in southern California started this approach several years ago, and in 1957 they organized a research and action program to improve techniques for building breaks. Numerous fuel-break demonstrations have been started and more are planned. Besides modifying fuels, fuel-breaks provide access for safer firefighting where modern techniques can be more effective. They also provide food and cover for wildlife which will not inhabit dense brush.

Now, the San Dimas Experimental Forest provides an area where an intensive fuel-break system can be developed as a model of the future for San Gabriel watersheds. A complete system has been planned, and chemical control of brush regrowth has started on breaks amounting to 3,000 acres (1,215 hectares).

Studies have also been started to improve the techniques of brush conversion on wildland areas. Sites have been classified and mapped. Several different plant species are being tested for adoption as permanent cover, and methods are being developed for their establishment on different sites. Included are plants reported to be fire-retardant or slow burning. Techniques of aerial and hand spraying to eliminate brush are being tested extensively.

Figure 11.--A ridge-top fuel-break. Dense brush fields are broken into manageable blocks of fuels by these wide strips which support light-volume fuels, such as grass.

Improvement of Water Yield

The major study aimed at management for increased water yield continues as part of the post-fire research program. A soil survey was made to locate the deep soils in Monroe Canyon. This watershed was seeded with a mixture of Wimmera ryegrass and blando brome. Areas with deep soil were cleared of unburned brush and sprayed with herbicide to prevent regrowth. Chemical control of woody plants in the canyon bottom area is continuing. Adjacent Volfe Canyon was not seeded, and here we will permit vegetation to regrow naturally. This watershed will continue to be the unmanaged control for comparison with Monroe Canyon.

We will also continue to manage Bell Watershed No. 2 for increased water yield. Here we have seeded the deeper-soil areas on side slopes to Wimmera ryegrass and blando brome and have sprayed these slopes to discourage chaparral regrowth. We have left the relatively unburned riparian zone intact. Our aim is to test the effect of the Bell No. 2 side-slope treatment on soil moisture, annual and seasonal water yield, flood peaks, and sediment production. We will use Bell Watershed No. 3 as a control.

EPILOGUE

By early 1963 our post-fire research program was in its third year. Its results and those from previous research will help improve and intensify the program as we move ahead to find out how to rehabilitate watersheds to control erosion and improve water yield. We look to the day when we can write prescriptions for improving watershed management practices in southern California. Our aim is to develop a pilot model to guide the management of some of the most valuable watersheds in the country.

APPENDIX

Table 1.--San Dimas Experimental Forest watershed areas

Watershed	Square miles	Acres	Range in elevation
			Feet
	MAJOR		
San Dimas	15.75	10,080	1,500-5,500
Big Dalton	4.46	2,855	1,700-3,500
	INTERMEDIATE		
San Dimas			
Wolfskill	2.39	1,530	1,700-5,200
Fern	2.14	1,370	2,600-5,500
Upper East Fork	2.14	1,370	2,600-5,200
East Fork	5.48	3,500	1,900-5,500
North Fork	4.23	2,710	1,900-4,500
Main Fork	13.14	8,410	1,600-5,500
West Fork	1.72	1,100	1,600-3,100
Dalton			
Bell	1.36	870	1,900-3,500
Volfe	1.16	740	1,900-3,500
Monroe	1.37	875	1,800-3,400
	SMALL		
Bell			
No. 1	.121	77	2,500-3,400
No. 2	.158	100	2,500-3,500
No. 3	.097	62	2,500-3,400
No. 4	.058	37	2,500-3,100
Total	.434	276	--
Fern			
No. 1	.055	35	4,500-5,400
No. 2	.063	40	4,500-5,400
No. 3	.084	53	4,500-5,400
Total	.202	128	--

Table 2.--Monthly climatic data, San Dimas Experimental Forest, Tanbark Flat field headquarters (elevation 2,800 feet)

Month	Rainfall, 32-year average	Evaporation[1] 25-year average	Air temperature Absolute maximum	Air temperature Absolute minimum	27-year monthly mean
	- - - Inches - - - -		- - - Degrees F. - - -		
October	1.1	5.6	120.0	25.5	61.1
November	2.1	3.7	87.0	28.0	53.9
December	4.8	2.4	84.5	21.5	49.5
January	5.2	2.3	84.0	18.0	46.8
February	5.5	2.4	83.0	22.0	47.7
March	4.1	3.4	80.0	24.0	49.3
April	2.5	4.1	90.5	26.0	53.7
May	0.6	5.6	100.0	28.5	57.1
June	0.1	7.0	101.0	33.0	63.7
July	([2])	9.7	121.0	39.0	72.1
August	0.1	9.6	107.0	38.0	72.1
September	0.3	8.2	108.0	37.5	69.8
Annual average	26.7	64.0	--	--	57.9

1/ Weather Bureau type evaporation pan.

2/ Trace.

Table 3.--Annual climatic data, San Dimas Experimental Forest, Tanbark Flat field headquarters (elevation 2,800 feet)

Year	Rainfall	Evaporation	Air temperature: Absolute maximum	Air temperature: Absolute minimum	Annual mean
	Inches	Inches	Degrees F.	Degrees F.	Degrees F.
1933-34	24.4	--	104.0	30.0	60.9
1934-35	34.8	--	96.0	25.0	56.8
1935-36	24.3	67.6	101.5	29.0	57.7
1936-37	43.8	67.9	98.0	19.0	58.7
1937-38	48.1	65.8	101.0	30.0	57.8
1938-39	27.0	72.6	100.5	22.0	59.4
1939-40	22.0	77.7	99.5	30.5	58.1
1940-41	48.2	61.4	95.5	32.0	56.3
1941-42	16.7	70.0	99.0	25.0	58.1
1942-43	45.2	70.1	101.5	26.5	56.1
1943-44	33.5	59.8	103.0	27.0	55.3
1944-45	29.7	59.9	97.0	26.5	58.0
1945-46	27.0	63.4	100.0	27.0	58.0
1946-47	27.6	63.5	100.5	27.0	58.3
1947-48	15.8	70.0	103.5	24.0	56.2
1948-49	16.9	64.7	100.0	18.0	54.5
1949-50	20.8	64.1	107.0	22.0	57.5
1950-51	11.5	72.4	102.0	23.0	59.6
1951-52	41.1	57.5	98.5	22.5	56.7
1952-53	15.5	61.5	105.0	25.5	57.7
1953-54	24.9	61.4	102.0	28.0	58.8
1954-55	19.9	61.4	108.5	24.0	57.3
1955-56	20.2	60.8	104.0	24.0	57.6
1956-57	19.8	59.9	103.0	20.0	58.2
1957-58	48.1	50.2	103.0	26.0	57.9
1958-59	14.3	53.6	93.1	35.2	60.2
1959-60	13.9	61.4	121.0	21.0	60.8
Annual average	1/ 26.7	64.0	--	--	57.9

1/ 32-year average based on San Dimas records 1933 through 1960 and Los Angeles County records from 1928 through 1932.

Table 4.--Disposition of rainfall on the San Dimas lysimeters[1]

Vegetation	Runoff	Infiltration[2]	Percolation	Loss[3]
	Inches depth			
Bare	13.0	7.7	0	7.1
Pine	5.6	15.1	0	15.1
Chamise	4.1	16.6	0	16.5
Grass	4.0	16.7	1.7	15.3
Buckwheat	3.5	17.2	0	17.2
Scrub oak	3.3	17.4	0	17.5

1/ Rainfall = 20.7 (10/1/52 - 9/30/56; range from 16.01 to 25.39 inches).

2/ Not adjusted for interception loss.

3/ Loss = Rainfall - (runoff and seepage ± soil moisture storage during period). Includes evaporation from soil, transpiration, and interception loss.

Table 5.--Disposition of annual rainfall in Monroe Canyon, 1938-1939 to 1952-1953

Disposition	Driest year 1950-1951	Wettest year 1940-1941	15-year average 1938-1953
	Inches		
Rainfall	12	52	27
Interception	2	5	3
Evapotranspiration	10	14	12
Total loss	12	19	15
Streamflow yield	(1/)	11	3
Groundwater yield	(1/)	22	9
Total yield	(1/)	33	12

1/ Trace.

Table 6.--Design of erosion control study watersheds

Broadcast seeding	Treatment				
	None	Trench	Channel checks	Barley	Combinations[1]
None	[2] 0544	0552	0546	0512	0555
Low density ryegrass	0560	0550	0517	0542	0553
High density ryegrass	0505	0545	0541	0543	0551
Low density perennials	0506	0519	0513	0514	0520
High density perennials	0503	0554	0516	0507	0508

[1] 0555 = Trench, channel checks, barley
0551 = Trench, channel checks, barley, high density rye
0508 = Trench, channel checks
0553 = Trench, barley
0520 = Channel checks, barley

[2] The four digits signify watershed number; the first two identify the major watershed, the last two identify the drainage within the major watershed. See also map inside back cover.

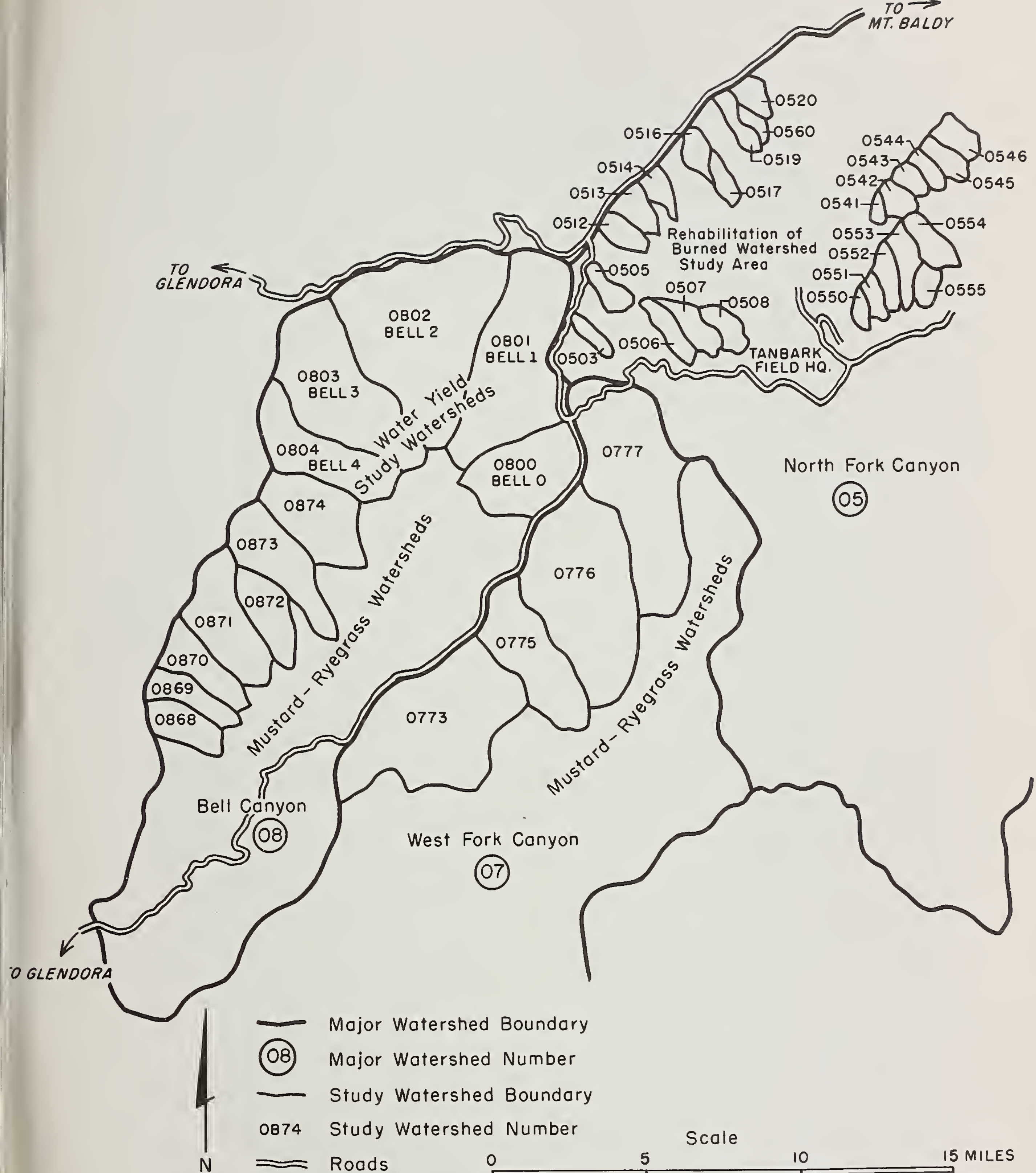
Table 7.--Pertinent facts on costs and materials in the Erosion (First-Aid) Study

TRENCHES		
Density	6 miles on 48 acres	
Storage	Dead storage of 3 inches of rain or 550 cubic yards of debris per acre per trench	
Cost	Labor	$ 86 per acre
	Tractor	114 per acre
	Total	$ 200 per acre

BARLEY CONTOUR ROW-PLANTING	
Seeding rate	150 lbs. per acre
Fertilizer rate	140 lbs. of diammonium phosphate per acre
Construction	15 man-days per acre 200 miles of line on 43 acres
Cost	$140 per acre

CHANNEL CHECKS	
Construction	3 man-days per foot of dam height (range from 3 to 6 feet high)
	Average 18 sacks of cement per dam, 6 to 1 mixture with soil
Density	46 dams on 44 acres
Average cost	$146 per dam (range $190 to $300)

GRASS SEEDING	
Helicopter costs for large areas at 10 lbs. per acre	$1.00 per acre
Helicopter costs for small areas (less than 10 acres) at 10 lbs. per acre	2.00 per acre
Seed costs for common ryegrass and mustard	.60 per acre
Seed costs for perennial grass mixture	2.00 to 7.00 per acre



Location of new study watersheds established as part of the San Dimas Experimental Forest Emergency Research Program.